THE WESTERN SIERRA MADRE OF THE STATE OF CHIHUAHUA, MEXICO.

BY

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The region comprised in Western Chihuahua, eastern Sonora, and southward in Mexico along the zone of mountains known as the Western Sierra Madre is practically a terra incognita to geologists and geographers. It includes the region left uncoloured on Costillo's geological map of Mexico as being unknown. Here and there mining engineers have examined bits of property for individual or corporate mine owners; but their reports rarely contain any structural data, and are seldom published in journals. The archæologist has penetrated into some of the mountain fastnesses, but he has given us scarcely a glimpse of the physiographic wonders of the region. No correct map of the mountains and rivers is in existence; but the railroad surveys now under way, in the effort to connect the high plateau with the Pacific coast region, should ere long furnish us with valuable data for one.

With the prospect, therefore, of traversing virgin territory, Professor Robert T. Hill and the writer* turned their faces toward the Southwest last winter, and spent several weeks in a remarkable series of cañons and mesas which will be described in a summary manner in the present communication, which gives some of the results of our joint observations. Our route led us southwestward across the Chihuahua desert province over the new Rio Grande, Sierra Madre and Pacific Railway to its present terminus at Nuevas Casas Grandes, Chihuahua, about 150 miles from El Paso, Texas, and from the very beginning the journey was suggestive.

The stratified beds of the arid and semi-arid regions of western America have given rise to much discussion as to their origin. Great lakes have been assumed to account for the extensive terraces, but it is difficult to conceive of the permanent or even protracted existence of large bodies of water under the conditions obtaining in the region. The cycle of the "mesa," or desert, formations was made clear by this little railroad journey across the arid bolsons to Lake Guzman and thence up the Casas Grandes, or

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San Miguel River. Under the influence of the great diurnal changes of temperature of the elevated plateau, and consequent expansion and contraction, the volcanic materials making up the mountains crack and disintegrate. The fragments as they descend the slopes become smaller, and soon come within the transporting power of the heavy winds which often prevail upon the plateaux.

The broken-down material is rapidly carried into the basins which lie between the numerous old centres of eruption and gradually fills them. From time to time the water collects in these depressions, and more or less temporary ponds are formed, which act like settling tanks—a term suggested by Professor Hill. Well-stratified beds thus originate within the wind-drifted areas and between beds showing little or no stratification. This explains the occurrence of some of the lenticular deposits of adobe clay in the strata composing the mesas. Robert T. Hill and others have written much upon the geology of desert and arid regions, but this explanation of the origin of some of the adobe clay deposits seems to have been overlooked.

The particular feature of the copious drainage of the high plateaux of the Western Sierra Madre is that most of the streams either dry up in the desert or flow into lakes which have no outlet. The Conchos, however (a tributary of the Rio Grande), is slowly working its way back toward the high plateau from the east; while the Yaqui and its branches, the Mayo and other Pacific rivers, are cutting into the plateau from the west with greater rapidity.

Lake Guzman, eighty miles from El Paso, is one of the largest of the desert lakes. It is 25 miles long and from 10 to 15 miles wide, and the evaporation from its surface is said to amount to seven feet per annum. The lake is reported to have been entirely dried up in August, 1904. The principal stream flowing into Lake Guzman is the Corralitos, or Casas Grandes River, and we followed this nearly to its source. Like other streams flowing into deserts, the maximum volume of this river is not near its mouth, but is near its entrance into the region where evaporation equals or exceeds precipitation.

The river which is known as the Corralitos for part of its course and the Casas Grandes for the rest is formed by the union of the San Miguel and Piedras-Verdes Rivers about ten miles south of the town of Casas Grandes, which received its name from neighbouring extensive prehistoric ruins. The San Miguel is the principal of these tributaries, and should give its name to the whole river, or

else the name Corralitos should be applied to the whole, the name Casas Grandes not being sufficiently distinctive on account of other regions of extensive ruins in Mexico. Many rivers in Mexico are known by different names in different parts of their courses—a practice which leads to much unnecessary confusion in geographic nomenclature.

Most of the mountains in sight from the railroad are volcanic in origin, but the Sabinal Mountains, about 100 miles from El Paso, are granitic in character, overlain by "porphyry" and by limestone of Cretaceous age. This is the location of the San Pedro group of silver and lead mines. Advancing southward from the end of the railroad as far as the Aros (Yaqui) River, 80 miles in an air-line, the rocks are almost exclusively volcanic, mostly rhyolite and andesite and their accompanying tuffs and dikes, together with comparatively local sandstones and conglomerates which have been derived directly from the volcanic materials and which represent ancient mesa and fresh-water basin formations. East of Hacienda San Diego blue limestone, probably of Cretaceous age, occurs in the foothills, and is quarried on a small scale for burning into lime.

About fourteen miles south of San Diego we began our ascent from the Chihuahua desert to the high plateau by way of the San Miguel cañon, and followed up its winding course for ten or twelve miles. The river is in a period of rejuvenation, and cuts a narrow, deep gorge 300 to 500 feet deep in a well-dissected plain which rises gradually to the cliffs forming the walls of the outer or upper cañon. The whole cañon is six or seven miles wide and about 1,800 feet deep. The principal rocks exposed are rhyolite flows and tuffs, but basalt occurs at the northern end of the cañon, and rounded andesite hills are under the rhyolite cap toward the south. The scenery is varied and beautiful.

Following the Arroyo Metate and another great ravine without a name, we climbed out of San Miguel cañon, and came upon the great plateau at 6,500 feet,* after passing over the outer rim of the cañon at 7,200 feet above the sea. The plateau is divided up into great haciendas or cattle-raising estates, the most valuable portions of which are immense nearly level plains or basins, most of which have no drainage outlet. The extensive plain, or prairie, known as the Llano Cristo forms a portion of the San Miguel hacienda, one of many belonging to General Luis Tarrazas, Governor of the

* All the elevations given in this article were determined by means of an aneroid barometer.

State of Chihuahua. The plateau is a constructional plain formed by the upper surface of rhyolite flows, with its hollows partly filled by the wash from the higher portions.

FIG. 1—YAQUI (ARÓS) CAÑON, NEAR GUAYNOPITA RIVER, IS 5,200 FEET LOWER THAN DISTANT RIM. INNER GORGE ABOUT 2,000 FEET DEEP.

The surface features of these plains would form an interesting topic for geographic study. Part of the Llano Cristo has been captured by the San Miguel (Casas Grandes) drainage; but much

of it is still independent, and none of the water falling upon this portion of the high plateau of Mexico reaches either ocean. The Llano Cristo contains some of the sources of the San Miguel River,

FIG. 2.—YAQUI (AROS) CAÑON AT GUAYNOPITA, 5,200 FEET DEEP. LOWER GORGE 1,800 FEET DEEP.

and is about 2,500 feet above the arid waste in which that stream loses itself.

Southward from Hacienda San Miguel our route lay along the

extensive prairies of the high mesa and across the spurs sent down from the mountain ranges, which traverse the plateau in a general north-south course. The mountains rise only from 1,500 to 2,500 feet above the mesa, and rarely is there a peak the altitude of which is more than 9,000 feet above the sea. All appear to be of volcanic origin, rhyolite and andesite lavas and tuffs predominating. The mesa itself gradually rises toward the south, and in the Llano Bavicora, a beautiful prairie 20 or 30 miles across, within the Hearst estate, is 7,000 to 7,100 feet in elevation. Moctezuma Pass (7,282 feet) is gained and crossed with scarcely a realization that the so-called "continental divide" has been traversed. The site of a large prehistoric village or city is indicated by the numerous mounds of the gently-rounding plain which forms the "Pass."

The inland drainage ceases here, and we are upon the edge of the Pacific drainage system, which is gradually "robbing" the plateau drainage. The newly-established lumber camp of Diedrick is in the mountains, just west of the summit of the plateau at Moctezuma Pass. Here the mountains rise abruptly to fully 9,000 feet above tide, and the trail to Guaynopita passes into the great cañon of the Yaqui River (here known as the Aros) at an elevation of 8,330 feet.

The view rivals that of the Grand Cañon of the Colorado. The Aros cañon is from 8 to 10 miles wide, and the river is from 4,500 to 5,000 feet below the highest points of the rim. From one point there may be seen nineteen flows of lava, one above another, with intervening beds of tuff and local conglomerate. The section here exposed gives additional support to the theory of mesa formation above expounded. Where the trail crosses the river (4,400 feet A. T.) there is a heavy bed of andesitic lava, showing the ropy character of the original surface of the flow. A thin bed of sandstone lies directly upon the lava, showing that this volcanic stream was covered with water soon after its extrusion.

Guaynopita, our next objective point, is a little mining camp hidden in the deep recesses of the Aros cañon, thirty miles by trail west of Diedrick. In reaching the camp we pass the ruins of an old arrastra, or mill, and the slag-pile from a neighbouring ancient furnace, where the Mexicans, generations ago, treated the copper, gold, and silver ores of the region. The romance and tragedy of mining have been carried through all these marvellous ravines, gorges, and cañons. At Guaynopita itself there is a splendid example of intrusive granite, associated with limestone. The limestone appears to be of late Cretaceous age; hence, the granite

is post-Cretaceous. Beautiful over-thrust faults are shown in the limestone, and in places metamorphism of the rock has gone so far as to produce schist. The ores (mostly chalcopyrite, cuprite,

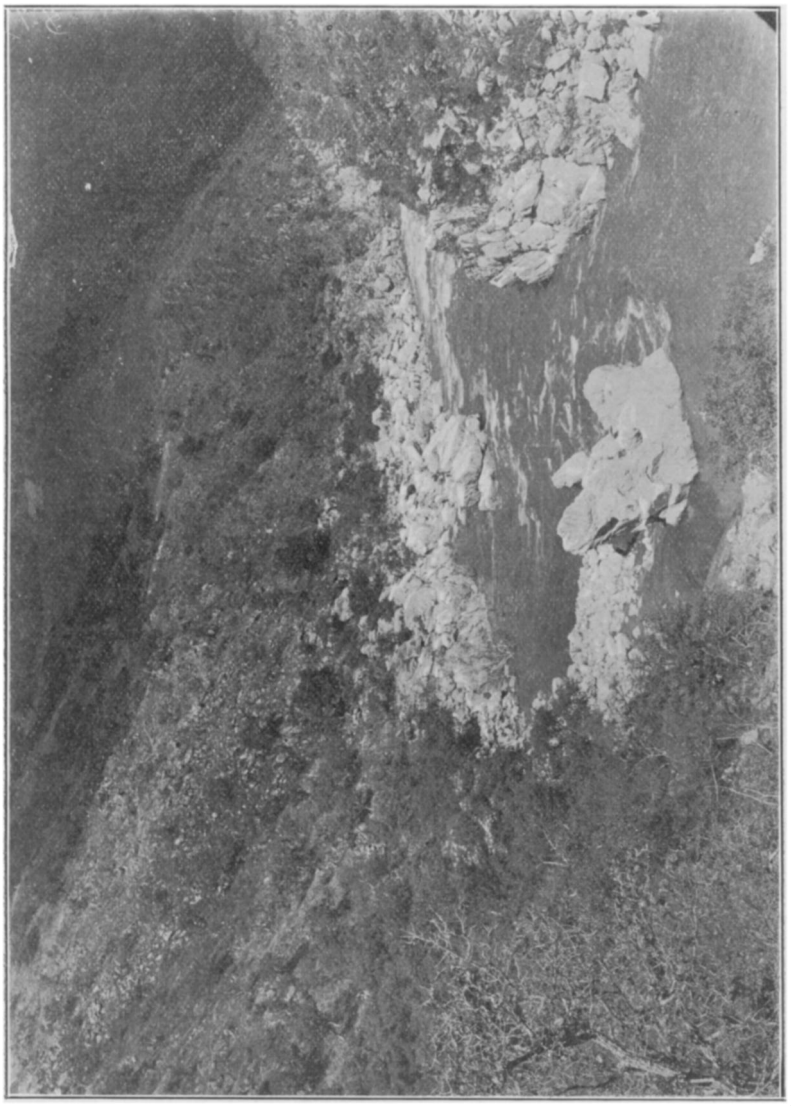

FIG. 3.—YAQUI (AROS) RIVER AT GUAYNOPITA. SHOWS ABANDONED CHANNEL AT LEFT OF PRESENT COURSE.

and tetrahedite) occur disseminated through the granite and concentrated in quartz veins which traverse granite and limestone alike. The little district of Guaynopita is one of the most inter-

esting geological regions in existence, and several forms of ore deposits occur therein.

Leaving Guaynopita, our course lay somewhat east of south for four days along the high mesa, between the Aros River on the east and an important tributary, the Tutuaca, on the west. The mesa, or series of mesas, extending southward between these two rivers has a gentle dip toward the east and south; hence, the natural course of the streams of this region at first was toward the southeast, and the smaller streams still preserve this consequent course; but the master river, the Yaqui (Aros), and the Verde, the Tutuaca, and the Mulatos pursue an inverted course. The Chico alone of the great tributaries of the Yaqui (Aros) preserves its consequent course along the eastern slopes of the Candelaria Mountains. In several places the table-land is reduced to a narrow divide between the eastward and westward flowing drainage; but everywhere the western slopes are the steeper—the heads of the streams are being constantly pushed toward the east.

Twenty-five miles southeast of Guaynopita we encountered the old Temosachic-Dolores trail, and its well-worn mule-tracks looked like a highway across the Mesa Venado. For generations this was the route traversed by the hundreds of pack-trains needed for carrying supplies from Chihuahua to the mines of the Sierra Madre and for bringing back ore and bullion. Very recently a new route leading to the railway at Miñaca, with gentler grades, has been established farther south by American enterprise. Mesa Venado is several miles long and more than a mile wide; and lying as it does 7,400 feet above the sea, it supports a magnificent forest of the long-leafed sugar-pine. The timber of the high mesa is the real incentive for pushing forward the railroads, which are to make their way from the central plateau down to the Pacific Ocean.

Turning abruptly westward, we plunged from the Mesa Venado into a deep tributary arroyo of the Tutuaca, and made a complete cross-section of the Tutuaca cañon to Dolores. Rhyolite flows and ash-beds, and andesite flows and breccias, with an occasional bed of basaltic character, make up the foundation of the series out of which the gorges have been cut. Near the Tutuaca River there is a massive development of the conglomerate "mesa formation," corresponding to the La Brisca formation, which Hill has described from Sonora. These beds are hundreds of feet in thickness in places, but they appear to be local in development—the accumulation of "wash" in the basins of the original surface of the volcanic beds.

Where the trail crosses the Tutuaca the stream is about 125 feet wide and too deep for fording. The mining company at Dolores have built a primitive suspension bridge here for the convenient transfer of their freight. The water for the mill at the Dolores mine is pumped from the Tutuaca to a reservoir 1,700 feet above the river, which gives a head of 200 feet at the concentrator. The mine follows a siliceous vein carrying silver-bearing copper ore, which traverses a heavy bed of diabase. Several quartzose veins project like walls from the acid tuff beds of the region, and are the lodestone which attracted the ancients to the mineral deposits of Dolores and which has induced the modern miner to invest much money here.

Continuing southward from Dolores, we found the country more broken than it was on the east side of the Tutuaca; that is, the dissection of the mesas has continued farther and their tops are less extensive than farther east. At Yepachic, forty miles south of Dolores, we encountered the first agricultural Indian village we had seen since leaving Casas Grandes, a stretch of more than 125 miles in an air-line. The country is practically without permanent population, and it is only at rare intervals that one sees the ranch even of a squatter.

Our next objective point was Cerro Voludo, five miles southwest of Yepachic. The summit of this mountain (7,050 feet) is of densely-indurated rhyolite tuff, and is about at the altitude of the old mesa. Looking westward from Cerro Voludo, one gazes upon a wilderness of cañons and arroyos, with narrow ridges and sharp summits. The view is bounded by the profile of the edge of the great mesa between Trinidad and Mulatos. The topography is relatively old.

A few miles south of Cerro Voludo we leave the water-shed of the Yaqui River and descend 3,500 feet into the V-shaped cañon of the Rio de Mayo, here known as the Moris, which finds its way to the Pacific Ocean south of the mouth of the Yaqui.

In this cañon is to be found the best development that we saw of a dark blue conglomerate, apparently altogether of originally volcanic materials, which is older than the lighter-coloured, higher La Brisca formation. The dark blue conglomerate is massive, hundreds, if not thousands, of feet thick, is tilted at an angle of about 15° toward the southeast, and is separated from the later overlying beds by a long erosion interval, during which there was considerable deformation of the conglomerate. We propose to call this formation the Navosaigame. Water-worn fragments of bluish

limestone occurring loose in the river-gravel terraces of the cañon of the Mayo prove the existence farther upstream of marine beds, apparently of Cretaceous age.

FIG. 4.—CERRO VOLUDO. ALTITUDE, 7,050 FEET A. T.

The trail led out of the Mayo cañon over the Cumbre Potrero into the Arroyo Rosario, which is tributary to the cañon in which Ocampo is located. The region is one of decomposed tuffs and

lava beds lying unconformably upon the Navosaigame conglomerate, and the whole series is cut by dikes of all sizes. Ocampo is a celebrated mining camp, better known, perhaps, by its old name of Jesus Maria. From one mine alone, the Santa Juliana, $100,000,000 of silver bullion were taken by its Mexican owners during the last century, but the shaft and lower levels are now flooded. The cañon is so deep, narrow, and crooked that one does

FIG. 5.—CAÑON, RIO DE MAYO (MORIS), AT NAVOSAIGAME. 4,000 FEET DEEP.

not see the town resting in its bottom, 3,000 feet below the rim, until he is fairly on top of it.

The population of Ocampo varies greatly with the prosperity or adversity of the mines. It is said to be about 5,000 now; but it is hard to see where so many people can be stowed away, even in the Mexican fashion. The cabins cling close to the walls of the V-shaped cañon formed by the junction of the two arroyos to make the great cañon. The route out northeastward toward Pinos Altos and Miñaca leads up the eastern branch, "Arroyo San Juan," and 2,400 feet above the camp comes out on the great mesa in the

midst of a magnificent forest of giant spruces. At Pinos Altos (from which, by the way, all the "lofty pines" have long since found their way underground as mine timbers) there is a remarkable

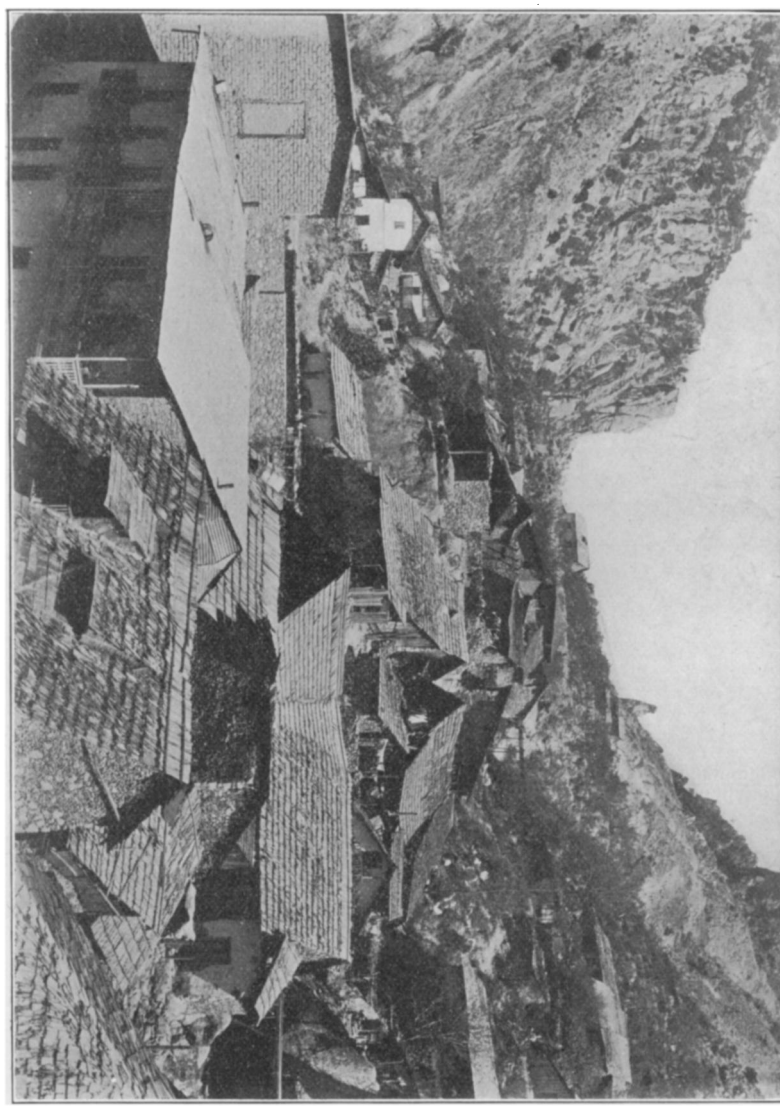

FIG. 6.—OCAMPO (JESUS MARIA). GREAT SILVER CAMP.

series of great quartz veins, which have resisted atmospheric destruction much more successfully than the country rock, and stand out from the mountain sides like gigantic buttresses.

The journey to Miñaca lies over the high mesa at altitudes from 6,900 to 7,300 feet above the sea. The mesa is partly dissected by the headwaters of the Rio de Mayo, the Tutuaca, the Verde, and their tributaries, and north northwest-south southeast ridges rise from 1,000 to 2,000 feet above the general level. The highest points are said to be about 9,000 feet above tide. Extensive flows of basalt are associated with the beds of rhyolite, andesite, and tuffs. Beds of sandstone, apparently old mesa formations, dip toward the northeast at an angle of about 20°.

Miñaca, the present terminus of the Chihuahua and Pacific Railroad, has been established in a beautiful basin-like mesa 7,200 feet above tide, near the base of Miñaca Butte, a mountain of obsidian, which received its name from its having been the last stronghold of General Miñaca, one of the heroes of Mexican history. The railroad is pushing on to the southwest, while toward the northwest a branch track is done as far as Temosachic. From Miñaca to Chihuahua the road traverses a series of bolsons, crosses the "continental divide" at an elevation of about 7,600 feet, and plunges through several picturesque gorges in basaltic and andesitic lava on its way to the bolson (4,633 feet A. T.*) in which the city of Chihuahua is situated.

The route from Chihuahua to El Paso is familiar ground to every traveller in Mexico. One long, narrow bolson succeeds another with gradually lowering altitude until the edge of the mesa on the border of the Rio Grande Valley is reached, when the grades become steeper for the last few miles into Ciudad Juarez. The region is arid and semi-arid, and toward the north one encounters the "bufas" or frog-like monoclinal mountains, the médanos or shifting sand-dunes, and the lagunas, all of which are like the features seen along the Sierra Madre and Pacific Railway.

* Elevation of the railway station at Chihuahua Mexican Central Railway folder.

American Museum of Natural History,
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